

## Brake Biasing via Balance Bar Declination

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**Abstract** - Braking System plays an essential role in controlling the vehicle. Under the condition of braking, turning or accelerating, there is dynamic weight transfer of vehicle around its roll centre. Therefore, there is a need of accurate brake biasing for better handling of the vehicle. The main objective of this research paper is to derive the relation between the angle of declination of brake bias bar and biasing ratio. Brake biasing is an important characteristic that drivers want to adjust according to their needs. The brake biasing is done between two master cylinders to get the required proportion of force to master cylinders from one pedal via a balance bar. The derivation is done through the balancing of force and moment. The brake assembly is also explained in this paper for a proper understanding of how brake biasing is done. The result of this derivation is proved through the CAE analysis of brake assembly. With the use of the derived relation, one could achieve the required biasing ratio with proper assembly if there are least losses in assembly.

**Key Words:** Balance bar, Brake power, Push rod, Master Cylinder

### 1. INTRODUCTION

Braking system is one of the most important part of vehicle subsystem. Function of a brake is to retard the speed of vehicle and hence, stop it completely. Brake involves frictional force to stop or control the vehicle. The perfect braking system will give desired deceleration according to drivers input to control the vehicle. The principle behind the brake is energy conversion, transforming kinetic energy into heat energy. This energy transformation occurs between brake disk and pads along with the clamping force applied by the brake caliper pads. Braking system plays an important part in vehicle in terms of safety and handling. The importance of dependable braking mechanism in any vehicle is paramount condition [1].

A balance bar is used in a dual master cylinder assembly, which divides the driver pedal force in between the two the master cylinders. It works on Balancing Moments [3]. In vehicle when braking force is applied, weight transfer occur from rear to front wheel. In order to achieve locking of wheel higher braking force is required on front wheels i.e. biasing should be more in front braking system. This weight transfer is also occurring while cornering of the vehicle, there the weight transfer takes place in lateral direction. Thus, this leads to use brake bias bar to vary braking force at different wheel. In hydraulic braking system it consists of master cylinder,

brake caliper and brake rotor. To vary braking force on wheel one must need to vary cylinder bore, pad material, piston diameter of caliper or diameter of brake rotor but all these changes can't be done easily. There comes the necessity of using brake bias generally known as balance bar. This balance bar allows us to make rapid adjustment according to track conditions, corners and driver preference [2].

The biasing done through balance bar divide the pedal force of driver and the force is transmitted to master cylinder via pushrod. The accurate motion of pushrod is important to transfer the divided force of balance bar to master cylinder for its proper functioning. To transfer the force from balance bar without any loss of force, pushrod should travel in straight line without any buckling and pushrod should travel maximum in master cylinder.

### 1.1 System Layout

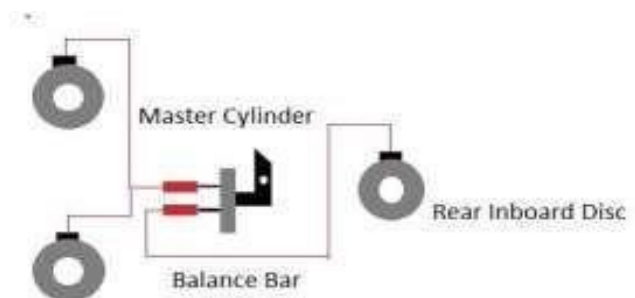


Fig. 1. Layout of Braking System

This layout of hydraulic braking system consists of outboard braking system in front and inboard braking system in rear. Same master cylinders of required piston diameters are used in both front and rear braking system. OEM Calipers of required piston diameter and number of piston are used according to braking force required at wheels. The connection between the master cylinder and caliper is done via combination of solid and flexible fluid line filled with brake fluid(dot3 or dot4). Pedal is mounted in front of master cylinder with appropriate leverage to amplify driver pedal force. The pushrod of master cylinder is attached to balance bar through fork joint or female heim joint and the balance bar is astride through the brake pedal via spherical plain bearing attach to the brake pedal. The spherical bushing allows the motion of balance bar in the plane of pushrod such that varying the length of the pushrod will lead to angle of balance bar with parallel axis of pushrods.

## 2. Assembly of balance bar

Brake pedal is manufactured by joining mild steel plate by en24 sleeve through welding. The en24 sleeve in pedal has bore for 10 mm plain spherical bearing which is locked in sleeve through internal circlip. Balance bar of material 20MnCr5 with outer diameter of 10mm and having thread of m10 with pitch 1.5mm astride the spherical plain bearing. The balance bar motion is locked about the axis of bearing through the external circlip of 10mm on both sides of bar. The pushrods have threads at one end. The push rod has fork joint/female heim joint at their end via threads to have connection with balance bar. From the fork joints/ female heim joint balance bar astride through them and these fork joint/ female heim joint are locked by m10 nut on both side each on balance bar, so that motion is almost straight while travelling inside cylinder. By varying pushrod length from cylinder piston to fork joint/ female heim joint, Biasing of balance bar could be achieve.

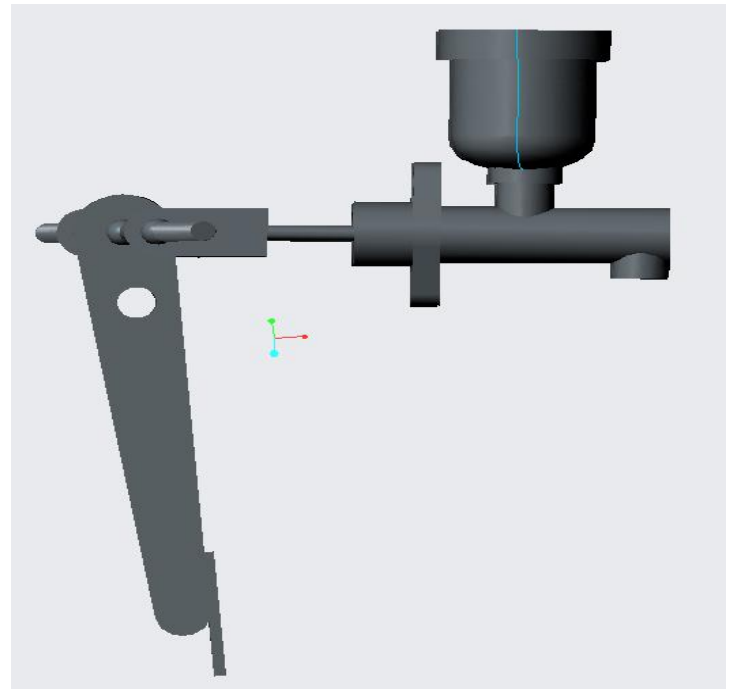


Fig. 3. Side View of Brake Assembly



Fig. 2. Cad Model of Brake Assembly

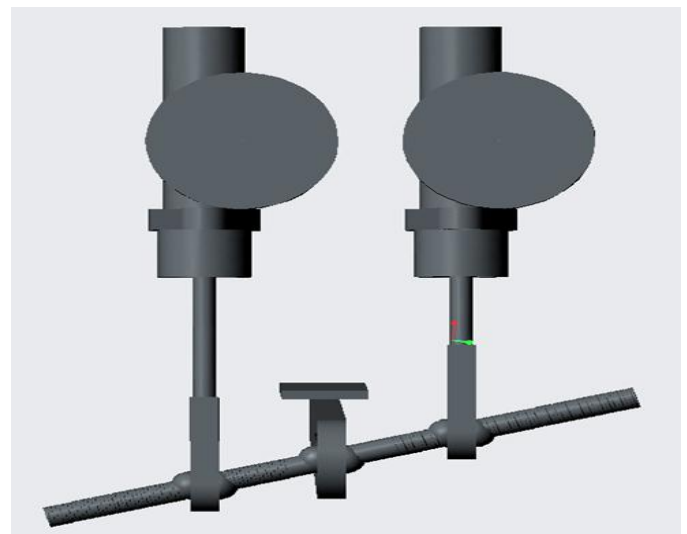


Fig. 4. Top View of Brake Assembly

## 3. Derivation of brake biasing relation

In this derivation we are concern with deriving the splitting of forces transfer to master cylinder via pushrod. As driver pedal force is applied on balance bar, this force is transfer to push rod to travel straight to maximize the travel inside master cylinder.

Now,  $F$  = Final pedal force applied by driver after multiplication of pedal ratio  
 Here, Pedal force is applied at the center of both the

master cylinder and the distance between both the cylinders is L.

**R<sub>a</sub>** = force transfer to cylinder at one side via pushrod  
**R<sub>b</sub>** = force transfer to cylinder at another side via pushrod  
**θ** = Angle of balance bar with respect to F

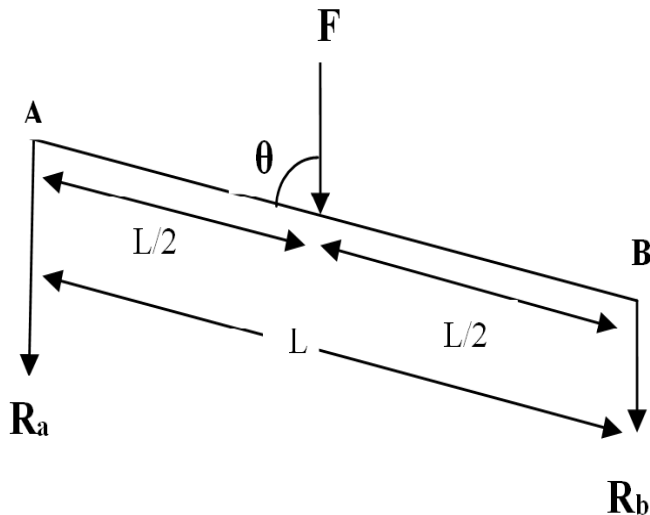


Fig. 5. Force distribution of brake assembly

Now, Splitting the Force Vector, F along balance bar

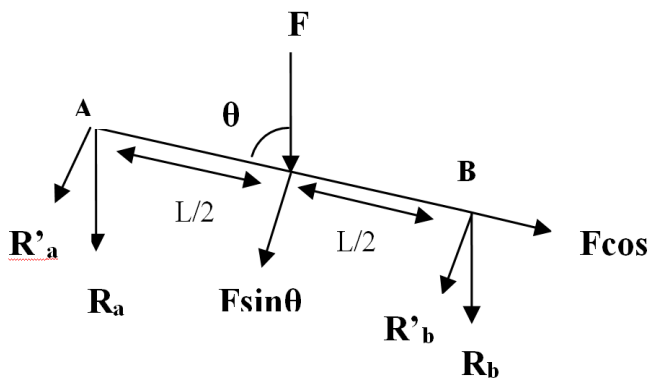


Fig. 6. R'<sub>a</sub> & R'<sub>b</sub> are forces parallel to F sin θ

Here R'<sub>a</sub> and R'<sub>b</sub> are forces split along F sin θ component at point A & B respectively.

So, equation of Bending Moment at A:

$$F \sin \theta \cdot L/2 + R'_b L = 0 \quad \dots(1)$$

$$\text{Thus, } R'_b = -F \sin \theta / 2 \quad \dots(2)$$

Here negative sign is for direction to balance moment equation i.e. it represents the reaction force of master cylinder, but we are concern only for splitting of pedal force towards master cylinder.

& by balancing Forces, we have

$$R'_a + R'_b = F \sin \theta \quad \dots(3)$$

From (2) & (3), we have

$$R'_a = R'_b = F \sin \theta / 2 \quad \dots(4)$$

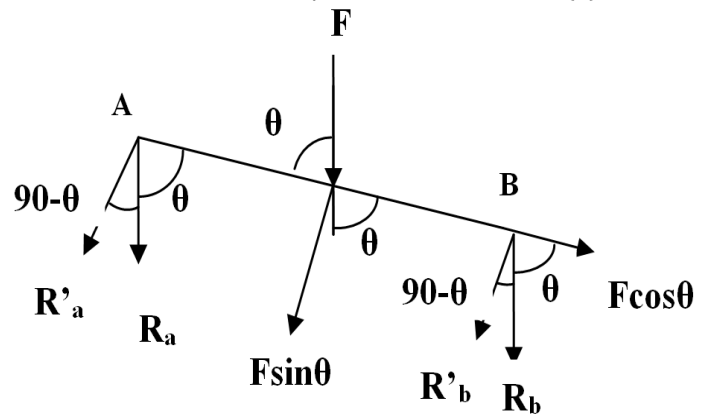


Fig. 7. Angle between different components of force

Now calculating resultant force,

At point A,

$$R_a = R'_a \cos(90-\theta) = (F \sin \theta / 2) \cos(90-\theta) = F \sin^2 \theta / 2 \quad \dots(5)$$

At point B,

$$R_b = (F \cos \theta) \cos \theta + F \sin \theta \cos(90-\theta) / 2$$

$$R_b = F \cos^2 \theta + F \sin \theta \sin \theta / 2 \quad [\cos(90-\theta) = \sin \theta]$$

$$R_b = \frac{2F(\cos \theta)^2 + F(\sin \theta)^2}{2}$$

$$R_b = \frac{F(\cos \theta)^2 + F}{2} \quad (\cos^2 \theta + \sin^2 \theta) = 1$$

$$R_b = \frac{F[(\cos \theta)^2 + 1]}{2} \quad \dots(6)$$

Thus, from (5) and (6), we have

$$R_a = \frac{F(\sin \theta)^2}{2}$$

$$R_b = \frac{F[(\cos \theta)^2 + 1]}{2}$$

Total,

$$R_a + R_b = \frac{F(\sin \theta)^2}{2} + \frac{F[(\cos \theta)^2 + 1]}{2}$$

$$= \frac{F[(\sin\theta)^2 + (\cos\theta)^2 + 1]}{2}$$

$$= \frac{F[1 + 1]}{2} = F$$

Hence Prove, The total pedal force **F** is split between two pushrods of master cylinder to achieve biasing via declination of balance bar.

NOTE: Here  $\theta \in (0,90)$

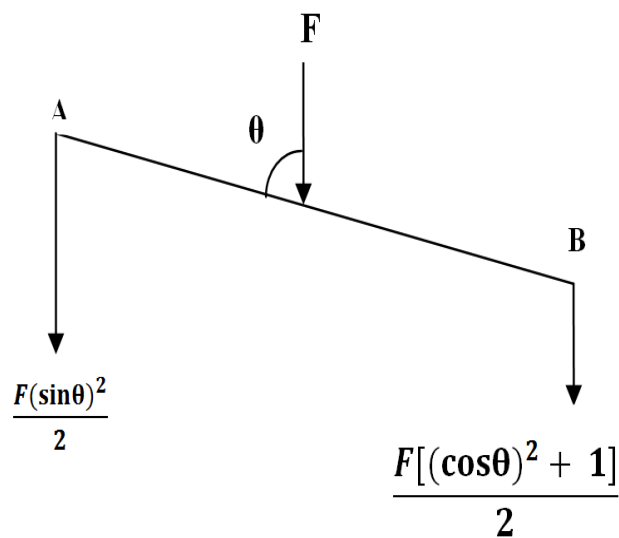


Fig. 8. Biasing through rotation of balance bar

#### 4. Simulation of brake assembly

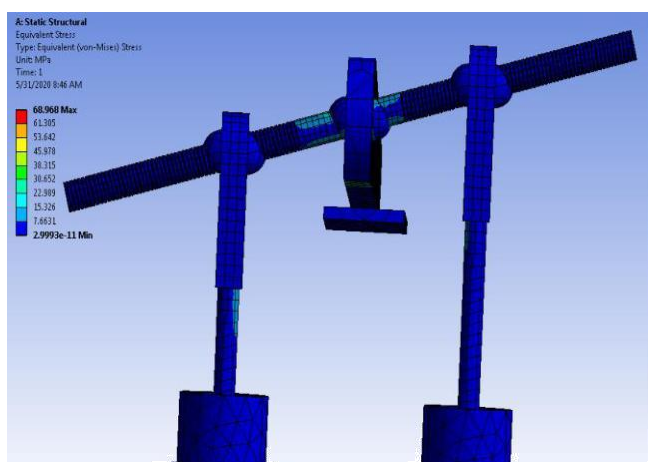


Fig. 9. Equivalent Stress

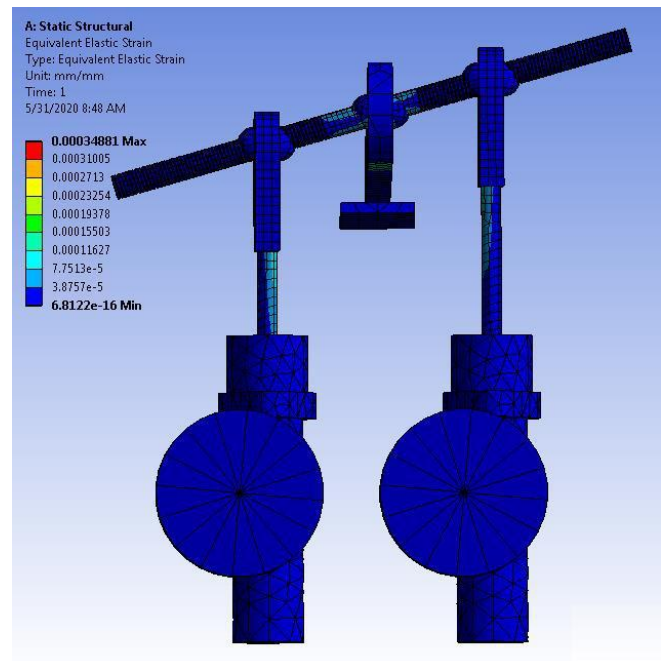


Fig. 10. Equivalent Elastic Strain

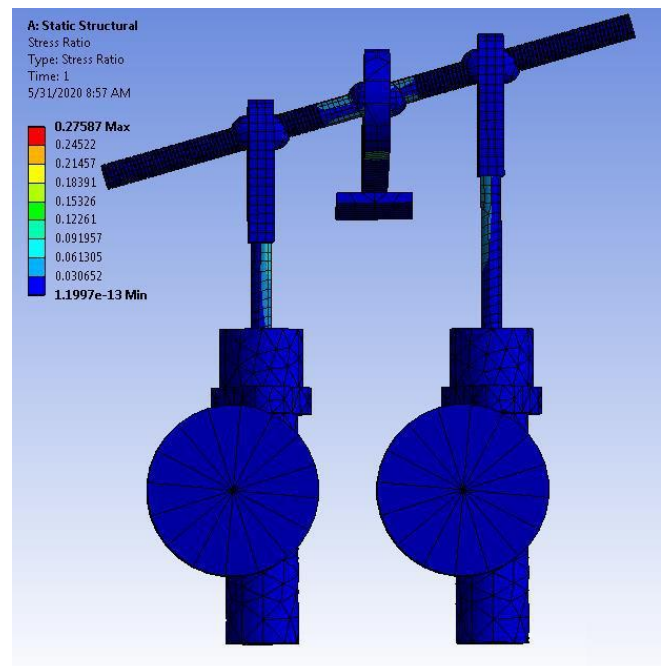


Fig. 12. Stress Ratio

From analysis we could observe on obtuse angle side of master cylinder force is more due to declination of balance bar. The pedal force is applied from footrest, then pedal force is transferred to balance bar via spherical bushing. From balance bar force is split between two master cylinder. The mounting of pedal and master cylinder are fixed support of assembly.





Fig. 13. Brake assembly

## 5. RESULT

The derived formula helps to find the angle of rotation of bias bar according to biasing ratio. For example

Total Pedal Force =  $F$

When angle of Rotation of balance bar i.e.  $\theta = 45^\circ$

By using (5) & (6), we have

$R_a = (0.25) F$

$R_b = (0.75) F$

Thus by angle of Rotation of bar at  $45^\circ$ , we will achieve 75:25 biasing ratio.

## 6. CONCLUSION

This paper has derived and proves the relation of biasing by declination of the balance bar by varying length of pushrod. The side of master cylinder which has acute angle has less biasing than the side having obtuse angle. By using this relation driver could varying biasing ratio from cockpit if proper assembly is install to vary pushrod length, changing position of master cylinder from cockpit otherwise one could do it manually. If proper assembly of brake is done i.e. link travel in straight line, both master cylinders are mounted proper & ...etc, then there is no loss of driver pedal force even declining of the balance bar.

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## BIOGRAPHY



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